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That I am knowledgeable in the English language and the Japanese language and that I believe the hereto attached English translation is a true and complete translation of Japanese Patent Application No. 2002-254201 filed August 30, 2002 based on which the priority right is claimed in connection with the present United States Patent Application Serial Number 10/525,092.

I hereby declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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[Abstract]

[Task]

This invention provides a polylactic acid fiber with outstanding abrasion resistance and an excellent ability to smoothly pass through processing and its manufacturing method.

[Resolution procedure]

A polylactic acid fiber characterized by containing a a 0.1to 5 wt% fatty acid bisamide and/or an alkyl substitute fatty acid monoamide with respect to the entire fiber.

[Selected diagrams] Figure 1

[Document] SPECIFICATION

[Title of Invention] POLYLACTIC ACID FIBER HAVING REMARKABLE WEAR RESISTANCE AND METHOD OF PRODUCTION THEREOF

[Claims]

[Claim 1] A polylactic acid fiber characterized by containing a 0.1 to 5 wt % fatty acid bisamide and/or alkyl-substituted fatty acid monoamide with respect to the entire fiber.

[Claim 2] The polylactic acid fiber according to Claim 1 characterized by having a spinning oil agent which contains at least one type of smoothing agent selected from a fatty acid ester, a polyhydric alcohol ester, an ether ester, silicon and/or mineral oil.

[Claim 3] The polylactic acid fiber according to Claim 1 or 2, wherein the b* value, which is the indicator for fiber tone color, is in the range of -1 to 5.

[Claim 4] Textile products characterized by utilizing at least one polylactic acid fiber according to any one of Claims 1 to 3.

[Claim 5] A method of producing polylactic acid fiber characterized by melt spinning polylactic acid containing 0.1 to 5 wt% fatty acid bisamide and/or alkyl-substituted fatty acid monoamide with respect to the entire fiber and by providing a spinning oil agent which contains at least one type of smoothing agent selected from a fatty acid ester, a polyhydric alcohol ester, an ether ester, silicon and/or mineral oil.

[Detailed Description of Invention]

[0001]

[Art Field of Invention][Technical field pertaining to the invention]

The present invention relates to a polylactic acid fiber having remarkable wear-resistance and the ability to smoothly pass through processing and a method of production thereof.

[0002]

[Conventional technology]

In the growing awareness on a global scale in recent years with regard to the environment, global warming produced by the enormous consumption of petroleum resources and the depletion of these resources that accompany this consumption have become subjects of great concern. With this as a background, naturally circulating environmentally responsive materials composed of raw materials from vegetation (biomass) which will ultimately decompose into water and carbon dioxide in the natural environment after use have become greatly desired.

[0003]

However, up to the present time the manufacturing costs of biodegradable polymers from the use of this biomass have been expensive, their low mechanical characteristics and thermal resistance have presented problems and they have not been widely used in plastics. At the present time, most attention is being focused on polylactic acid, which is one type of fatty acid family polyester, as a biodegradable polymer from biomass use which can resolve these problems. Polylactic acid is a polymer using lactic acid as a raw material that is obtained from the fermentation of starch extracted from plant material and among biodegradable polymers in use from biomass shows the best balance between mechanical properties, thermal resistance and cost. Thus, the development of resin products, fibers, films and sheets which use it is proceeding at a fever pitch.

[0004]

Agricultural materials and civil engineering materials that make the best use of biodegradability are being given priority in the development of polylactic acid fibers and for extensive use in the wake of this, applications are expected for use in clothing, for interior use such as in curtains and carpets, for use in automobile interiors and use in industrial materials.

[0005]

However, because polylactic acid fibers have a high surface friction coefficient, one drawback is that their abrasion resistance is inferior and no advances have been made in usage which requires abrasion resistance such as that for clothing, interiors and automobile interiors. For example, when used in such items as outerwear, uniforms and sportswear, particularly for such parts as shoulders, elbows, knees and the back of the pants which are frequently chafed in daily life, there is the major problem of lowered appearance quality because of fluff, whitening or shine and because color transfer to the innerwear occurs. Furthermore, because of frequent abrasion even when used for upholstery and carpets, there is the problem that fluff is produced, the fibers wear through and break, durability is extremely bad and color transfer occurs on clothing such as pants and hosiery.

[0006]

In order to evaluate the abrasion resistance of this type of polylactic acid fiber, the authors of this invention investigated its degree of abrasion fastness with the Color Fastness Rubbing Test stipulated in JISL 0849. In this evaluation method a dyed fiber product is rubbed with cloth and the color transfer onto the cloth evaluated. As a result, with polyethylene terephthalate or nylon, in contrast to the color fastness to rubbing attaining a level of 4 or

higher as long as ordinary dyes are used, for polylactic acid it is 1, an extremely low level. Consequently, when studying the surface condition of the fibers with a scanning electron microscope (SEM) after conventional polylactic acid fibers have been rubbed with cloth (comparative example 1), both polymer scraping and color transfer occur because the scraped polymers adhere to the cloth. For clothing use, because generally color fastness to rubbing must reach at least level 3 or above, development of polylactic fibers for this type of use has essentially been extremely difficult.

[0007]

Furthermore, problems are created even in the manufacturing process of textiles because of the high surface friction coefficient of polylactic acid fibers. For example, in the cloth cutting process, numerous layers of cloth are cut when superimposed but for polylactic acid cloth at this time, the cut pieces of cloth fuse together because a large amount of shear heat is generated between the cutter and the fibers. Furthermore, when polylactic acid cloth is sewn, at normal sewing speed there is a remarkably large friction force between the sewing machine needle and the fibers and the fibers become fused because of the heat generated by the friction which results in a decrease in the quality of the product, and because the polymers adhere to needle in the sewing machine, it is necessary to replace the sewing machine needles frequently so that essentially the process only proceeds at low speed and productivity is noticeably reduced.

[0008]

Additionally, the effects due to the high surface friction coefficient of polylactic acid fibers are not just limited to the problems of inferior abrasion resistance or the cloth manufacturing process mentioned above but extend also

to the unsatisfactory process that occurs when manufacturing the fibers. For example, in the melt spinning process, normally the thread passes through at a high speed of 1000-7000 meters per minute and because of the large amount of friction between the thread and the type of guide, fluff and thread breakage occur easily. Additionally, in the drawing process, the thread coils around the roller and thread breakage occurs easily. Furthermore, in the yarn crimping process and particularly in the false twisting process, because the friction force between the thread and the twister becomes excessive, thread breakage occurs frequently and the process essentially becomes a difficult one. In addition, because at knitting and weaving time there is not only friction between the thread and the metal but friction between thread and thread, the generation of fluff becomes pronounced and there is the problem that the ability to smoothly pass through processing and the quality of the cloth are greatly reduced. Because of the above, when polylactic acid fibers and their fiber products are manufactured, there is the critical problem that at the same time that the ability to smoothly pass through processing is bad and productivity is reduced, the quality is low because of the generation of fluff and abrasion.

[0009]

The high coefficient of friction of polylactic fibers which is the cause of these problems is considered to be due to the polymer substrate and is a problem which inevitably occurs with polylactic acid fibers.

[0010]

Incidentally, in the field of resin products, films and sheets, in order to improve the antiblocking properties of the chips and melt polymers or to improve the detachability of the compact from the mold or roller during the manufacturing process, smoothing agents are sometimes added. However, in the field of

fibers, because of uneven blending, thermal decomposition and bleedout of the smoothing agents, product quality is easily reduced because of the uneven physical properties of or uneven dyeing of the fibers so that up to the present time the tendency has been to avoid using these kinds of additives.

[0011]

There are very few examples of fibers with smoothing agents added to fibers but examples include ones in which fatty acid monoamides expressed by the general formula $RCONH_2$ (where R is an alkyl group) are added to the polylactic acid fibers with the objective of suppressing the speed of hydrolysis because of the water repellant properties provided (cf. patent document 1) but there has been absolutely no description regarding improvement in the abrasion resistance of polylactic acid fibers and improvement in the ability to smoothly pass through processing which are the objectives of this invention. To make sure of this, the authors conducted additional tests regarding polylactic acid fibers with added fatty acid monoamides and found it impossible to cause any improvement in the abrasion resistance of the polylactic acid fibers or bring about any improvement in the ability to smoothly pass through processing when manufacturing them (comparative examples 4, 5). It is presumed that the reason for this is that in order to increase the reactivity of its amide group, the fatty acid monoamide reacts completely with the polylactic acid at fusion time with the result that the percentage of the fatty acid monoamide contained in the fibers which can function as a smoothing agent decreases. Furthermore, there is the case that when the fatty acid monoamide reacts with polylactic acid, the molecular weight decreases as a result of cutting the molecular chain of the polylactic acid and the physical properties of the fibers deteriorate. Additionally, because fatty acid monoamides have large sublimability or because of inferior

thermal resistance, deterioration of the work environment due to the release of fumes or contamination on the guides or rollers due to bleedout and a decrease in work efficiency are caused. Furthermore, there is also the case that because the bled out fatty acid monomers cohere onto the surface of the fibers, uneven physical properties and uneven coloration in the fibers are incurred.

[0012]

Because of these problems, a polylactic acid fiber with both excellent abrasion resistance and the ability to smoothly pass through processing has been earnestly desired.

[0013]

[Patent document 1]

Patent Publication No. 8-183898 (pp. 2-4)

[0014]

[The problem the invention intends to resolve]

The task of this invention is to provide a polylactic acid fiber and its manufacturing method that overcome the above stated problems and that has excellent abrasion resistance and superior ability to smoothly pass through processing.

[0015]

[Steps to resolve the problem]

The above stated task is achieved through a polylactic acid fiber characterized by containing a fatty acid bisamide and/or an alkyl-substituted fatty acid monoamide of 0.1-5 wt% with respect to the whole fiber.

[0016]

Furthermore, it is achieved through a manufacturing method for a polylactic acid fiber characterized by melt spinning of polylactic acid which

contains a fatty acid bisamide and/or an alkyl-substituted fatty acid monoamide of 0.1-5 wt% with respect to the whole fiber and by providing a spinning oil agent that contains at least one type of smoothing agent selected from a multivalent alcohol ester, an ether ester, silicon or mineral oil.

[0017]

[Realized configuration of the invention]

A detailed explanation is given below with regard to this invention.

[0018]

The polylactic acid mentioned in this invention refers to one in which lactic acid oligomers from lactic acid or lactides are polymerized and when the optical purity of the L and D forms are 90% or above preferably has a high melting point. Furthermore, in a range within which the character of the polylactic acid is not vitiated, even when components beside lactic acid are copolymerized, it is permissible for it to contain additives such as polymers or particles beside lactic acid, flame retardants and antistatic charge agents. When the average molecular weight of the polylactic acid polymer is 50,000 to 500,000, the balance between the mechanical characteristics and formability is more favorable.

[0019]

The fatty acid bisamide referred to in this invention indicates a compound which has two amide bonds in one molecule such as a saturated fatty acid bisamide, unsaturated fatty acid bisamide and aromatic family bisamide with cited examples being methylene biscaprylic acid amide, methylene biscapric acid amide, methylene bislauric acid amide, methylene bismyristic acid amide, methylene bispalmitic acid amide, methylene bisstearic acid amide, methylene bisisostearic acid amide, methylene bisbehenic acid amide,

methylene bisoleic acid amide, methylene biserucic acid amide, ethylene biscaprylic acid amide, ethylene biscapric acid amide, ethylene bislauric acid amide, ethylene bismyristic acid amide, ethylene bispalmitic acid amide, ethylene bisstearic acid amide, ethylene bisisostearic acid amide, ethylene bisbehenic acid amide, ethylene bisoleic acid amide, ethylene biserucic acid amide, butylene bisstearic acid amide, butylene bisbehenic acid amide, butylene bisoleic acid amide, butylene biserucic acid amide, hexamethylene bisstearic acid amide, hexamethylene bisbehenic acid amide, hexamethylene bisoleic acid amide, hexamethylene biserucic acid amide, m-xylylene bisstearic acid amide, m-xylylene bis-12-hydroxystearic acid amide, p-xylylene bisstearic acid amide, p-phenylene bisstearic acid amide, p-phenylene bisstearic acid amide, N, N'-distearyl adipic acid amide, N, N'-distearyl sebacic acid amide, N, N'-dioleyl adipic acid amide, N, N'-dioleyl sebacic acid amide, N, N'-distearyl isophthalic acid amide, N, N'-distearyl terephthalic acid amide, methylene bishydroxystearic acid amide, ethylene bishydroxystearic acid amide, butylene bishydroxystearic acid amide and hexamethylene bishydroxystearic acid amide. Furthermore, the alkyl-substituted fatty acid monoamide mentioned in this invention refers to a compound with a structure in which an amide hydrogen such as a saturated fatty acid monoamide or an unsaturated fatty acid monoamide is substituted with an alkyl group with such examples cited as N-lauryl lauric acid amide, N-palmityl palmitic acid amide, N-stearyl stearic acid amide, N-behenyl behenic acid amide, N-oleyl oleic acid amide, N-stearyl oleic acid amide, N-oleyl stearic acid amide, N-stearyl erucic acid amide and N-oleyl palmitic acid amide. A substituted group such as a hydroxol group may be introduced into the structure of the said alkyl group with, for example, methylol stearic acid amide, methylol behenic acid amide, N-stearyl-12-hydroxystearic acid amide and N-oleyl 12 hydroxystearic

acid amide considered to be substances included in the alkyl-substituted fatty acid monoamides of this invention.

[0020]

This invention utilizes fatty acid bisamides or alkyl substitute fatty acid monoamides but when compared to normal fatty acid monoamides, the amide reactivity of their compounds is low and a reaction with polylactic acid is difficult to bring about at the melt process time. Furthermore, because there are a considerable number of high molecular weight substances, generally they are characterized as having good thermal resistance and as being difficult to sublime. For fatty acid bisamides in particular, because the reactivity of the amide is even lower, it is difficult for it to react with the polylactic acid and its thermal resistance is good because of the high molecular weight, and because it is difficult to sublime, it can be used as a more preferable smoothing agent.

[0021]

For this invention, as a smoothing agent it is necessary to have a fatty acid bisamide and/or an alkyl-substituted fatty acid monoamide containing 0.1-5 wt% with respect to the entire fiber. By having the contained amount of the said fatty acid amide be 0.1 wt% or higher, the surface friction coefficient of the fiber is reduced and it is possible to give the abrasion resistance to the fiber product required for use in clothing and to give it durability for repeated use. Additionally, it is possible to control the fusion of the cloth from the cutter or high speed sewing needle in the cloth manufacturing processand to improve the ability to smoothly pass through processing. Furthermore, with the content amount of the said fatty acid amide at 5 wt% or lower, microscattering of the fatty acid amide is feasible and it is possible to prevent the occurrence of uneven physical properties and uneven dyeing in the fibers. The preferable content

amount of the said fatty acid amide is 0.5 to 3 wt%. In this invention, the said fatty acid amide may be alone or a number of components may be mixed together. When mixed, the mixture should contain 0.1to 5 wt% with respect to the entire fiber.

[0022]

It is preferable that for the polylactic acid fiber of this invention a spinning oil agent be provided that contains a smoothing agent. It is preferable that the smoothing agent as a substance which causes a reduction in the coefficient of friction of the fiber and the metal be, for example, a fatty acid ester, a polyhydric alcohol ester, an ether ester, silicon or mineral oil. Furthermore, these smoothing agents may be used singly and may also be used when a number of components are mixed together. In particular a fatty acid ester or mineral oil is more preferable as the smoothing agent suitable for the polylactic acid fiber. Additionally, a polyether-based smoothing agent gives outstanding thermal resistance but because the coefficient of friction of the fiber and metal sometimes rises, it is preferable to avoid its use.

[0023]

There is no particular limit to the fatty acid esters referred to in this invention but cited examples include esters of monohydric alcohols such as methylolate, isopropyl myristate, octyl palmitate, oleyl laurate, oleyl olate, isotridecylstearate and monohydric carboxylic acid, esters of monohydric alcohols such as dioctyl sebacate or dioleoyl adipate and polyhydric carboxylic acid, esters of polyhydric alcohols such as ethylene glycol diolate, trimethylolpropane tricaprilate, glycerol triolate and monohydric carboxylic acid and alkylene oxide added esters such as lauryl (EO) $_n$octanoate. By providing an oil agent which contains a smoothing agent described above for the polylactic

acid fibers, thread breakage or fluff generation in the spinning and pulling processes and winding around the roller can be suppressed. Furthermore, even regarding the false twisting process of conventional polylactic acid fibers when the ability to smoothly pass through processing is defective, the frictional force between the thread and the twister is reduced and because thread breakage is suppressed, the ability to smoothly pass through processing can be favorably enhanced. Additionally, in the knitting process, the friction between the thread and metal or thread to thread is diminished and by controlling the generation of fluff, it is possible to obtain a high quality fiber product.

[0024]

In this invention, for components constituting the oil agent, in addition to the smoothing agent it is permissible to use substances in which emulsifying agents or, when needed, antistatic agents, ionic surfactants, binders, rust prevention agents, preservatives and antioxidants are appropriately combined, cause the oil agent to emulsify in water, lower the viscosity, adhere to the thread line and improve permeability.

[0025]

The content amount with respect to the entire oil agent in the smoothing agent is preferably 30 to 95 wt%. When the content amount with respect to the entire oil agent in the smoothing agent is 30 wt% or above, the surface friction coefficient of the fiber is greatly reduced and it is possible to improve the ability to smoothly pass through processing, the quality of the fiber and the fiber product. Furthermore, when the content amount is 95 wt% or below, the dispersibility of the oil agent in water is improved and it is possible to check uneven adherence of the oil agent when the content amount is being

applied to the fiber. The content amount with respect to the entire oil agent in the smoothing agent is more preferably 55 to 75 wt%.

[0026]

In order for the polylactic acid fiber of this invention to be extensively used for important color tones in clothing, interiors and automobile interiors, the b* value, which is the standard for yellow tone coloration, should preferably be -1 to 5 and more preferable -1 to 3. Furthermore, in polylactic acid fibers which contain a fatty acid monoamide which is the conventional technology, the b* value is high and sometimes the yellow color tends to be strong. This is believed to be because in addition to the thermal degradation of the fatty acid monoamide which is inferior in thermal resistance, the fatty acid monoamide reacts with the carbonyl group of the polylactic acid polymer at melt formation time forming a diacetamide group. In contrast to this, because the fatty acid bisamide or the alkyl-substituted fatty acid monoamide of this invention has excellent thermal resistance and the reactivity of the amide group is low, coloring of the fiber occurs with difficulty.

[0027]

In order maintain the ability to smoothly pass through processing and to maintain the mechanical strength of the product with the polylactic acid fiber of this invention at a sufficiently high level, it is preferable if the strength is 2.0 cN/dtex or above. Furthermore, when the ductility of the polylactic acid fiber of this invention is 15 to 70%, the ability to smoothly pass through processing when making the fiber product is favorably improved. When the shrinkage in boiling water is 0 to 20% for the polylactic acid fiber of this invention, the dimensional stability of the fiber and fiber product is favorably improved. Additionally, when the U%, which expresses the uneven thickness of the thread, is 1.5% or less,

uneven dyeing occurs with difficulty and a dyed fiber product of high quality is favorably obtained. It is more preferable if the U% is 1.0% or less.

[0028]

The fineness of the polylactic acid fiber of this invention has no particular limit but when used in clothing, it is preferable if the overall fineness of multifilaments is 500 dtex or less and 0.1 to 10 dtex for single filament fineness. Generally, inferior abrasion resistance of polylactic acid fibers becomes more noticeable as the fineness of single filament gets smaller but in the polylactic acid fiber of this invention abrasion resistance is maintained even when the single filament fineness is small.

[0029]

Regarding the cross section shape of the polylactic acid fiber having excellent anti-hydrolytic properties of this invention, it is possible to freely select a circular cross section, a hollow cross section, a trilobal cross section, a multi-leaf cross section and even other atypical cross sections. Furthermore, there are no particular limits to length or width in the shape of the fiber and long fibers may be either multifilament or monofilament.

[0030]

There are no particular restrictions on the manufacturing method for the polylactic acid fiber of this invention and it is possible to manufacture it by melt spinning of polylactic acid containing 0.1 to 5 wt% of a fatty acid bisamide and/or alkyl-substituted fatty acid monoamide with respect to the entire fiber and by providing a spinning oil agent containing at least one type of smoothing oil agent selected from fatty acid esters, polyhydric alcohol esters, ether esters, silicon or mineral oil.

[0031]

Polylactic acid can be synthesized using heretofore known methods but polylactic acid itself has excellent tone color and it is preferable if the remaining oligomers or monomers such as lactide are reduced. For the specific method used, as for example described in Japan Unexamined Patent Publication No. H7-504939, it is preferable to use a metal deactivator or antioxidant, keep the polymerization temperature low and control the catalyst addition rate. Furthermore, by processing the polymer at reduced pressure and extracting it with chloroform, it is also possible to significantly reduce the amount of the remaining oligomers and monomers.

[0032]

There is no particular restriction to the method for including fatty acid bisamides and/or alkyl-substituted fatty acid monoamides in the polylactic acid fiber and the following method is cited as an example. First, for the kneading process, after the polylactic acid and fatty acid bisamide and/or alky substituted fatty acid monoamide are dried, they are placed in a nitrogen sealed extrusion kneading machine and the chip for kneading made. Secondly, melt spinning takes place by placing the kneading chip in the spinning machine. In the kneading process a method is also ideally used in which the kneading chip is made containing a high percentage of the fatty acid bisamide and/or the alkyl-substituted fatty acid monoamide (master chip formation) and when this is put into the spinning machine, it is blended with a common polylactic acid chip and diluted so that the fatty acid bisamide and/or alkyl-substituted fatty acid monoamide is brought to the desired content amount. Furthermore, in the melt spinning process, it is also possible to knead the polylactic acid and fatty acid amide more minutely by placing a stationary kneader in the spinning pack. Because cohesion of the fatty acid amide or bleedout onto the fiber surface

causes a decrease in workability due to contamination on the guide or on the roller and cause uneven physical properties and uneven dyeing in the fiber product, it is preferable to have the fatty acid amide minutely dispersed in the polylactic acid during the kneading process and the melt spinning process.

[0033]

Furthermore, it is also permissible to use the same process for kneading and melt spinning and it is possible to use methods such as the following examples. In a first melt spinning method, after the polylactic acid and the fatty acid bisamide and/or alkyl-substituted fatty acid monoamide are dried, they are placed in the nitrogen sealed extrusion kneading machine, the kneaded polymer melt of the polylactic acid and fatty acid bisamide and/or alkyl-substituted fatty acid monoamide kneaded in the extrusion kneading machine is introduced into the spinning machine, is further finely kneaded by the stationary kneader placed in the spinning pack and is discharged from the cap. Additionally, in a second melt spinning method the polylactic acid and fatty acid bisamide and/or alkyl-substituted fatty acid monoamide are melted separately, the melts are introduced into the spinning machine, mixed more minutely by the stationary kneader placed in the spinning pack and discharged from the cap.

[0034]

The fatty acid bisamide and/or alkyl-substituted fatty acid monoamide should contain 0.1 to 5 wt% with respect to the total amount of the blended polymer. When the content amount of the said fatty acid amide is 0.1 wt% or more, the surface friction coefficient of the fiber can be reduced, fusion of the cloth due to the cutter and high speed sewing needle during the manufacturing process of the cloth can be suppressed and the ability to smoothly pass through processing can be improved. Furthermore, when the content amount of the

said fatty acid amide is 5 wt% or less, deterioration of the work environment due to the fumes created during the kneading or spinning process by sublimation or decomposition of the excess fatty acid amide that bleeds out from the melt polymer or a reduction in workability from contamination of the extrusion kneading machine or melt spinning machine due to sublimation or decomposition of excess fatty acid amide can be prevented.

[0035]

Furthermore, when the content amount of the said fatty acid amide is 5 wt% or less, favorable conditions are produced because there is very little cohesion of the fatty acid amide in the melt polymer during the kneading or spinning process and the thermal deterioration of the fatty acid amide or its reaction with the polylactic acid is suppressed and the b* value can be 5 or less. In addition, because bleedout from the melt polymer of the fatty acid amide is suppressed during the spinning process, extrusion of the polymer from the cap is stable and the suppression of uneven thread is favorably enhanced. The content amount of the said fatty acid amide is preferably 0.5-3 wt%. Additionally, the fatty acid bisamide and/or alkyl-substituted fatty acid monoamide used in this invention are difficult to sublime compared to fatty acid monoamides of conventional technology and because their thermal resistance is excellent, they make favorable smoothing agents. Particularly for the fatty acid bisamide, because the reactivity of the amide is further lowered, this makes it difficult for it to react with the polylactic acid, the thermal resistance is good because of the high molecular weight, it is difficult to sublime, improvement in abrasion resistance of the fiber product is remarkable and it is possible to control the fumes from the kneading and spinning processes. In addition, it is possible to control uneven thread by decreasing the bleedout from the polymer of the fatty

acid amide and by stabilizing the extrusion of the polymer from the cap. Accordingly, when this thread is dyed, it is possible to control uneven dyeing and to obtain a high quality dyed fiber product.

[0036]

After the thread from the melt spinning is discharged from the cap and the thread line is cooled and hardened by the chimney, the spinning oil agent containing the smoothing agent is provided from the lubrication guide or oiling roller and then the thread line is taken up by the roller. When the pick up speed is in particular 2500 meters per second or more, because of the large amount of friction between the fiber and the guide, the selection of the spinning oil agent at this time is extremely important. At this point, as a substance that will cause a decrease in the coefficient of friction of the thread and metal, it is preferable that the smoothing agent contained in the spinning oil agent be a fatty acid ester, a polyhydric alcohol ester, an ether ester, silicon or mineral oil. Furthermore, these smoothing agents may be used as single components and also used mixed with a number of components. As a smoothing agent particularly suitable for the polylactic acid fiber, a fatty acid ester or mineral oil is even more preferable. Additionally, a polyether-based smoothing agent has outstanding thermal resistance properties but because there is the case that the coefficient of friction of the fiber and metal rises, it is preferable if it is avoided. By providing an oil agent in the polylactic acid fiber which contains a smoothing agent as described above, it is possible to control thread breakage or the generation of fluff during the spinning and drawing processes and to control coiling around the roller. Furthermore, even with regard to the false twisting process in which the ability of conventional polylactic fibers to smoothly pass through processing is inferior, because the abrasion between the thread and the

twister is reduced and thread breakage is suppressed, the ability to smoothly pass through processing is favorably enhanced. In addition, because the friction between the thread and metal or between threads is decreased in the knitting process and the creation of fluff is suppressed, it is possible to obtain a high quality fiber product.

[0037]

It is preferable if the content amount of the smoothing agent with respect to the entire oil agent is 30 to 95 wt% and even more preferable if it is 55 to 75 wt%. When the content amount of the smoothing agent with respect to the entire oil agent is 30 wt% or more, the coefficient of friction for the surface of the fiber is greatly reduced and it is possible to improve its ability to smoothly pass through processing and the quality of the fiber and fiber product. Furthermore, when the content amount is 95 wt% or less, the dispersion of the oil agent in water is improved and it is possible to control uneven adhesion of the oil agent when it is applied to the fiber. It is more preferable if the content amount of the smoothing with respect to the entire oil agent is 55 to 75 wt%.

[0038]

In the case of long fibers, the thread line is temporarily rolled up as a cheese package and subsequently it is pulled and undergoes heat processing. If the spinning speed which is the circumferential speed of the first take up roller is 2500 to 7000 meters per minute at this time, uneven thread is favorably reduced. Additionally, if the draw temperature is 80 to 150ºC, uneven thread is favorably reduced. Furthermore, if the heat processing temperature is 120 to 160ºC, shrinkage of the polylactic acid fiber in boiling water is reduced and thermal dimensional stability is favorably improved. In addition, in the case when high strength is required as in use in industrial materials, multistage pulling

may also be implemented. Furthermore, when necessary, because of such processes as the false twisting process, push-in process and mechanical yarn crimping, the polylactic acid fiber may be crimped. Additionally, in the melt spinning it is also possible to use a direct spinning draw method in which it is not temporarily rolled up but is drawn and heat processed in its unrolled up state.

[0039]

On the other hand, in the case of short fibers, the taken up thread lines are doubled and after being temporarily received by a banker and after further doubling and made into a tow, they are drawn and mechanically crimped and after the oil agent suitable for the next step is provided, they are cut. During the drawing, taking it into consideration that the tow is thick and its heat transfer is deficient, it is preferable if steam drawing or liquid drawing is adopted. It is preferable that the temperature at this time be 75 to 100ºC.

[0040]

Further, when it is unwoven, either the above described short fiber or a method in which the unwoven form process continues with so-called spunbond or meltblow spinning may be used.

[0041]

With the polylactic acid fiber of this invention, textiles, knitted fabrics and unwoven fabrics may variously adopt its fiber structure.

[0042]

Furthermore, the polylactic acid fiber of this invention may also be used together with materials composed of raw materials derived from plant matter. For example, it may be combined with such natural fibers as silk and cotton or such regenerated fibers as rayon or acetate fiber to produce a mixed weave or mixed knit product. Additionally, the polylactic acid fiber of this

invention with its outstanding anti-hydrolytic properties can be used as a binder and in unwoven fabrics or in a compact mixed with pulp.

[0043]

The polylactic acid fiber of this invention can not only be used in such clothing items as shirts, blousons or pants, it may also be suitably used in clothing materials such as brassiere cups and padding, for interior use such as in curtains, carpets, mats, wallpaper or furniture, in automobile interiors, belts, nets, rope, heavy fabrics, different types of bags, industrial use of sewing thread, felt, unwoven fabrics, filters or man-made artificial lawns.

[0044]

[Embodiment]

A detailed explanation of this invention is given below using an embodiment. Furthermore, the measuring method in the embodiment used the following method.

[0045]

A. Average molecular weight

Gel permeation chromatography [Shimazu LC-10AD] by Shimazu Company was used and polystyrene was measured as the standard.

[0046]

B. TG (thermogravimetric measurement)

A MacScience Company made [TG-DTA 2000S] was used and the decrease in the weight decrease rate of an approximately 10 mg test sample was measured as it was heated from 30ºC with a temperature rise speed of 10ºC per minute.

[0047]

C. Strength and ductility

An Orientech Co., [Tensilon UTM-100III] was used and at room temperature (25ºC) with the initial test sample length = 200 mm and pull speed = 200 mm per minute, a load-ductility curve was determined. Next, the load value at breakage time was divided by the initial fineness and this was taken as the strength and the extension at breakage time was divided by the initial test sample length and the strength/extension curve was determined as the ductility. (In compliance with JISL 1013).

D. Shrinkage in boiling water

Determined from the equations below.

[0048]

Shrinkage in boiling water (%) = [(L0-L1)/LO)] x 100 (%)

LO: The original length of the reel when the stretched thread is reeled up and the initial load is measured at 0.088 cN/dtex

L1: The reel length when the reel with the measured LO is essentially processed for 15 minutes in boiling water in a load-free state and then after air drying under a preliminary tension of 0.088 cN/dtex.

E. U%

A Zellweger Uster Inc. made [Wooster Tester-1 Model C] was used and uneven thread thickness measured by measuring in normal mode at 200 m/min x 1 minute.

[0049]

F. CR value

The crimped yarn was reeled up, processed for 15 minutes in boiling water in an essentially load-free state and air-dried for 24 hours. A suitable load of 0.088 cN/dtex was put on this sample, it was immersed in water and after

two minutes the reel length L' 0 was measured. Next, the 0.088 cN/dtex load was removed from the water, a 0.0018 cN/dtex microload substituted and the reel length L' 1 measured after two minutes. Then the CR value was calculated by the following formula.

[0050]

$$CR\ (\%) = [(L'\ 0 - L'\ 1)/L'\ 0] \times 100\ (\%)$$

G. Tone color (b* value)

On a transparent plate the fiber sample was carefully laminated to the degree that the substrate color could for all intents and purposed be disregarded and then wrapped and using a Minolta Company made [Spectrophotometer-CM-3700d] the b* value was measured. At this time, measurements were made using a D_{65} (color temperature 6504K) in a 10º visual field.

[0051]

H. Abrasion resistance [color fastness to rubbing (dry type)]

After a dyed cloth sample was rubbed back and forth 100 times with cotton cloth, the degree of color transfer to the cloth was determined to be 1 to 5 using the grayscale. (In compliance with JIS L 0849).

I. SEM observation

Using a Hitachi made [Hitachi S-3000N], the surface of the cloth after the rubbing test was observed.

[0052]

J. Uneven dyeing

Dyed cloth obtained in the Embodiment and comparative examples was visually evaluated. ○ and above was passing.

[0053]

□: Absolutely no uneven dyeing

○: Some uneven dyeing

□: Conspicuous uneven dyeing

×: Significant uneven dyeing

K. Spinnability

The number of times thread breakage occurred in a 1 t spinning test was examined. Thread breakage of 4 times/t or below was passing.

[0054]

L. Drawability

144 spindles were installed on a stretching machine, drawing of 3kg per spindle was conducted and the drawability evaluated according to the equations below. Draw superiority rate = 90% is passing

[0055]

Draw superiority rate (%) = ((number of spindles – thread breakage spindles – occurrence of coiling around a roller)/number of spindles) x 100 (%)

M. Weaving performance

Using a WJR (waterjet weaving machine) with the number of revolutions of the machine at 600 to 800 rpm the number of times the machine stopped due to thread breakage was examined. Machine stoppage of six times per day per platform or less was passing.

[Manufacturing Example 1] (manufacturing the polylactic acid)

A lactide made from optically pure 99.5% L lactic acid with bis (2-ethylhexanoate) tin as a catalyst (lactide to catalyst mole ratio = 10,000:1) underwent polymerization in a nitrogen atmosphere at 180ºC for 140 minutes and polylactic acid P1 was obtained. The average molecular weight of the obtained polylactic acid was 135,000.

[Manufacturing Example 2] (manufacturing polylactic acid containing 4 wt% EBA)

After the P1 and ethylene bisstearic acid amide (EBA) [NOF Corporation made [Alflow H-50S]] were dried, heated and melted, EBA was measured to obtain P1:EBA = 96:4 (weight ratio) and while being rapidly and continuously added to P1 it was provided to a kneading extrusion machine having two shafts with a cylinder temperature of 220 ºC and polylactic acid P2 containing 4 wt% EBA was obtained.

[Manufacturing Example 3] (manufacturing polylactic acid containing 7 wt% EBA)

Other than changing P1:EBA = 93:7 (weight ratio), the manufacturing method was identical to Manufacturing Example 2 and polylactic acid P3 containing 7 wt% EBA was obtained.

[Manufacturing Example 4] (manufacturing polylactic acid containing 4 wt% KBA)

Other than changing EBA to m-xylylene bisstearic acid amide (KBA) [Nippon Kasei Chemical Co. made [Slipacks PXS]], the manufacturing method was the same as in Manufacturing Example 2 and polylactic acid P4 containing 45 wt% KBA was obtained.

[Manufacturing Example 5] (manufacturing polylactic acid containing 4 wt% SS)

Other than changing EBA to the alkyl substituted monoamide N-stearyl stearic acid amide (SS) [Nippon Kasei Chemical Co. made [Nikkaamide S]], the manufacturing method was the same as in Manufacturing Example 2 and polylactic acid P5 containing 4 wt% SS was obtained.

[Manufacturing Example 6] (manufacturing polylactic acid containing 4 wt% BA)

Other than changing EBA to behenic acid monoamide (BA) [NOF Corporation made [Alflow B-10]], the manufacturing method was the same as in Manufacturing Example 2 and polylactic acid P6 containing 4 wt% BA was obtained.

[Manufacturing Example 7] (manufacturing polylactic acid containing 4 wt% SA)

Other than changing EBA to a stearic acid amide monoamide (SA) [NOF Corporation made [Alflow S-10]], the manufacturing method was the same as in Manufacturing Example 2 and polylactic acid P7 containing 4 wt% SA was obtained.

[0056]

Embodiment 1

Chip blending (EBA 1 wt%) was conducted to get a P1:P2 = 3:1 weight ratio, this was placed in hopper 1 and after this chip was melted at 220ºC in extruder 2, a melt polymer was introduced into the spinning pack 4 placed in pinblock 3 heated to 220ºC and extruded from cap 5 (Figure 3). After the spun twisted thread line 7 was cooled and solidified by air drying at 25ºC by the chimney 6, the smoothing oil agent for the fatty acid ester thread and the spinning oil agent (15% concentration) containing 40 wt% (isotridecyl stearate 20 wt% + octylpalmitate 20 wt%) with respect to the thread were 1 wt% applied by the focused lubrication guide 8 and the thread was twisted by the twist guide 9. Then, after being taken up by the No. 1 unheated take-up roller 10 with a circumferential speed of 3000 meters per minute, it was wound by means of the No. 2 unheated take-up roller 11 and the wound up thread 12 was obtained. Its

spinnability was excellent and no thread breakage or generation of fluff was observed. Furthermore, there were almost no fumes directly under the cap.

[0057]

After the obtained undrawn yarn 13 was preheated by the 90ºC No. 1 hot roller 15 through the feed roller 14, it was stretched 1.45 fold, was heat set by the 130ºC No. 2 hot roller 16, coiled by the cold roller 17 and an 84 dtex, 36 filament, round cross section thread 18 was obtained (Figure 4). Its drawability was also excellent and its drawing superiority rate was above 98% and no fluff adhesion to the guide was observed.

[0058]

The obtained thread with a strength of 3.5 cN/dtex, 38% ductility, 7.0% shrinkage in boiling water and 0.7% U% exhibited excellent physical thread properties. Furthermore, with a 1.2 b* value and the tone color was excellent with almost no yellow coloration.

[0059]

A plain weave fabric (weave density: warp 95 stiches/inch, weft 80 stiches/inch) was obtained using this fabric in the warp and woof. Furthermore, a 300 turn per meter S twist was achieved in the warp. There was almost no thread breakage or generation of fluff during the twisting process or weaving process demonstrating an excellent ability to smoothly pass through the weaving process. Additionally, this cloth underwent a dyeing process under the conditions given below. The obtained cloth was both flexible and soft and exhibited an outstanding texture in which there was very little mechanical creak characteristic of polylactic acid fibers. Furthermore, in addition to having remarkable chromogenic properties, the quality was outstanding without any uneven dyeing.

[0060]

Additionally, when its color fastness to rubbing was measured, its abrasion resistance at level 4 was excellent. Further, results from observing the surface of the cloth after the rubbing test with an SEM showed almost no abrasion of the thread (Figure 1). Also, industrial cutting and industrial sewing were performed and there was no fusion on the cut portion of the cloth after cutting, sewing machine needle contamination was also decreased and an excellent ability to smoothly pass through processing was obtained. In addition, shirts were made using this material and after they had been worn for a month, a durability test was conducted and there was no fluff, whitening or shine, demonstrating outstanding product durability.

<Cloth process conditions>

· Refining: soda ash (1g/l), surfactant (0.5g/l), 98ºC x 20 minutes

· Intermediate set: 140ºC x 3 minutes

· Dye: Dianix Navy Blue ERFS 200 (2% owf), ph regulator (0.2g/l), 110ºC x 40 minutes

· Soaping: surfactant (0.2g/l), 60ºC x 20 minutes

· Finishing set: 140ºC x 3 minutes

Embodiment 2

In a manner similar to Embodiment 1 only P2 (4 wt% EBA) was used, melt spinning and stretching were conducted and an 84 dtex, 36 filament trileaf cross section drawn yarn was obtained. Its spinnability was excellent and no thread breakage or generation of fluff was observed. However, because the large 4 wt% content amount of EBA compared to Embodiment 1, there were almost no problems but fumes were observed directly under the cap. Furthermore, its drawability was also excellent, its draw superiority rate was

above 98% and no adhesion of fluff on the guide was observed. With a strength of 3.1 cN/dtex, 39% ductility, 6.0% shrinkage in boiling water and a 1.5% U%, the obtained fiber exhibited excellent physical thread properties. However, the b* value of the stretched thread was high compared to Embodiment 1 but nothing that led to any problems but there was some suggestion of a yellow color.

[0061]

A plain weave fabric was made in a manner similar to Embodiment 1 with this thread and there was almost no thread breakage or generation of fluff in the twisting process and weaving process at this time demonstrating excellent ability to smoothly pass through the weaving process.

[0062]

Furthermore, a dyeing process similar to that of Embodiment 1 was carried out on this cloth. The obtained cloth was flexible and soft and showed an excellent texture with very little mechanical creak characteristic of polylactic acid fibers. Additionally, its chromogenic properties were excellent but some uneven dyeing was observed probably because the U% of the fiber was high compared to Embodiment 1 and there was some cohering of the EBA as compared to Embodiment 1.

[0063]

Further, its color fastness to rubbing was measured and its abrasion resistance at level 5 was outstanding. Additionally industrial cutting and industrial sewing were carried out using this dyed cloth, there was no fusion on the cut portion of the cloth when cut and there was a minute amount of contamination of the sewing needle demonstrating an excellent ability to smoothly pass through processing. Also, shirts were made using it and a

durability test performed after they had been worn for one month and there was no fluff, whitening or shine, demonstrating the outstanding durability of the product.

[0064]

Embodiment 3

A preparation of P1 and P2 with a weight ratio of 12.3:1 (0.3 wt% EBA) was made and in a manner similar to Embodiment 1 melt spinning and drawing were conducted and an 84 dtex, 36 filament drawn yarn was obtained. Its spinnability was excellent and no thread breakage or generation of fluff was observed. Additionally, its drawability was also excellent with a draw superiority rate of over 98% and no adhesion on the guide was observed. The obtained fiber demonstrated excellent physical thread properties with a strength of 3.6 cN/dtex, a ductility of 39%, a 7.5% shrinkage in boiling water and a 0.7% U%. Also, with a b* value of 0.8 the tone color was excellent with almost no yellow coloration.

[0065]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and there was almost no thread breakage or generation of fluff in the twisting process and weaving process, demonstrating an outstanding ability to smoothly pass through processing.

[0066]

In addition, this cloth underwent a dyeing process similar to Embodiment 1. The obtained fabric demonstrated an outstanding flexible and soft texture. However, because the EBA content amount was slight compared to Embodiment 1, some mechanical creak characteristic of polylactic acid fibers

remained. Additionally, along with excellent chromogenic properties there was no uneven dyeing and the quality was outstanding.

[0067]

Furthermore, when its color fastness to rubbing was measured it was at a passing level 3 but its abrasion resistance was inferior compared to Embodiment 1. In addition, industrial cutting and industrial sewing were conducted using this dyed cloth and compared to Embodiment 1 there was some slight fusion generated with the cut portions of the cloth during cutting time and also some slight contamination of the sewing needle demonstrating a sufficient ability to smoothly pass through processing. Also, shirts were made using it and a durability test performed after they had been worn for one month and although somewhat inferior to Embodiment 1, there was only slight fluff, whitening and shine demonstrating that it was a sufficiently durable product.

[0068]

Embodiment 4

The take-up roller circumferential speed was changed to 5000 meters per minute, the temperature of the first hot roller changed to 140ºC, the draw ratio was changed to 1.65 and the temperature of the second hot roller changed to 150ºC and in a manner similar to Embodiment 1 melt spinning and drawing were carried out and an 84 dtex, 24 filament drawn yarn was obtained. Its spinnability was excellent and there was no observed thread breakage of generation of fluff. Furthermore, its drawability was also excellent and the draw superiority rate was more than 98% and no adhesion of the fluff on the guide was observed. The obtained fiber exhibited excellent physical properties with a strength of 5.0 cN/dtex, a ductility of 22%, shrinkage in boiling water of 8.0% and

a 0.7% U%. In addition, with the b* value at 1.1, excellent color tone was obtained with almost no yellow tint.

[0069]

A plain weave cloth was made in a manner similar to Embodiment 1 and there was almost no thread breakage or fluff generation during the twisting process and weaving process at this time demonstrating an excellent ability to smoothly pass through processing.

[0070]

Furthermore, this cloth under went a dye process in a manner similar to Embodiment 1 and it was not only flexible and soft, it showed an outstanding texture with little mechanical creak characteristic of polylactic acid fibers. Additionally, along with excellent chromagenic properties, there was also no uneven dyeing and the quality was outstanding.

[0071]

Additionally, its color fastness to rubbing was measured and its abrasion resistance at level 4 was excellent. Further, industrial cutting and industrial sewing were performed using this dyed cloth, there was no fusion of the cut portions of the cloth at cutting time and there was almost no contamination of the sewing needle demonstrating its outstanding ability to smoothly pass through processing. Also, shirts were made using it, a durability test was performed after they had been worn for one month and there was no fluff, whitening or shine, demonstrating the outstanding durability of the product.

[0072]

Embodiment 5

With the take-up roller circumferential speed at 1500 meters per minute and the draw ratio at 2.4, melt spinning and drawing were conducted in a

manner similar to Embodiment 1 and an 84 dtex, 36 filament drawn yarn was obtained. Its spinnability was excellent and no thread breakage or generation of fluff was observed. Further, the drawability was also excellent, the draw superiority rate was more than 98% and no adhesion of fluff on the guide was observed. The obtained thread exhibited excellent physical thread properties with a strength of 3.5 cN/dtex, a ductility of 41%, a 7.0% shrinkage in boiling water and a 1.3% U%. Additionally, with a b* value of 1.3 the color tone was excellent with almost no yellow coloration.

[0073]

A plain weave fabric was made in a manner similar to Embodiment 1 using this thread and there was almost no thread breakage or generation of fluff in the twisting process and weaving process at this time demonstrating an excellent ability to smoothly pass through the weaving process.

[0074]

Furthermore, this cloth underwent a dyeing process similar to Embodiment 1. The obtained cloth not only was flexible and soft, it exhibited an excellent texture with only a slight mechanical creak characteristic of polylactic acid fibers. In addition, it had excellent chromagenic properties but because the U% was large compared to Embodiment 1, some slight uneven dyeing was observed compared to Embodiment 1.

[0075]

Additionally, when the color fastness to rubbing of this material was measured, its abrasion resistance at level 4 was outstanding. Further, industrial cutting and industrial sewing were carried out using this dyed cloth and there was no fusion of the cut portions of the cloth at cutting time and there was also very slight contamination of the sewing needle, demonstrating its

outstanding ability to smoothly pass through processing. Furthermore, shirts were made with this cloth and after they had been worn for one month, they underwent a durability test and there was no fluff, whitening or shine demonstrating the excellent durability of the product.

[0076]

Embodiment 6

A preparation of P1 and P2 with a 1:1 weight ratio (2 wt% EBA) was made, melt spinning and drawing were conducted in a manner similar to Embodiment 1 and an 84 dtex, 144 filament drawn yarn was obtained. Its spinnability was excellent and no thread breakage or generation of fluff was observed. Further, its drawabiltiy was excellent with a draw superiority rate of over 98% and no adhesion of fluff to the guide was observed. The obtained fiber demonstrated excellent physical thread properties with a strength of 3.4 cN/dtex, a ductility of 39%, a 7.5% shrinkage in boiling water and a 0.9% U%. Additionally, with the b* value at 1.2 the tone color was excellent with almost no yellow coloration.

[0077]

A plain weave fabric using this thread was made in a manner similar to Embodiment 1 and there was almost no thread breakage or generation of fluff during the twisting process and weaving process demonstrating its outstanding ability to smoothly pass through the weaving process.

[0078]

Further, this cotton fabric was dyed in a manner similar to Embodiment 1. The obtained fabric was not only flexible and soft, it exhibited an outstanding texture with very little mechanical creak characteristic of

polylactic acid fibers. Additionally, along with its excellent chromagenic properties, there was also no uneven dyeing and the quality was outstanding.

[0079]

Furthermore, when the color fastness to rubbing of this fabric was measured, its abrasion resistance at level 4 was excellent. Also, industrial cutting and industrial sewing were conducted using this dyed fabric, there was no fusion of the cut portions of the fabric at cutting time and there was also very little contamination of the sewing needle, demonstrating its excellent ability to smoothly pass through processing. In addition, shirts were made using this material and after they had been worn for one month, a durability test was performed with no fluff, whitening or shine being found, demonstrating outstanding product durability.

[0080]

Embodiment 7

Using P4 in place of P2 melt spinning and drawing were conducted in a manner similar to Embodiment 1 and an 84 dtex, 12 filament drawn yarn was obtained (1 wt% KBA). Its spinnability was excellent and no thread breakage or generation of fluff was observed. Additionally, no fumes were observed directly under the cap. Further, its drawability was also excellent with a draw superiority rate of over 98% and no adhesion of the fluff to the guide was observed. The obtained fiber exhibited excellent physical thread properties with a strength of 3.5 cM/dtex, a ductility of 39%, a 7.0% shrinkage in boiling water and a 0.8% U%. Also, with a b* value of 1.6 its tone color was excellent with almost no yellow coloration.

[0081]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and there was no thread shrinkage or fluff generation in the twisting process and weaving process, demonstrating its outstanding ability to smoothly pass through processing.

[0082]

Furthermore, this cloth was dyed in a manner similar to Embodiment 1 and the obtained cloth was not only flexible and soft, it exhibited an excellent texture with very little mechanical creak characteristic of polylactic acid fibers. Additionally, together with its excellent chromagenic properties, there was also no uneven dyeing and its quality was outstanding.

[0083]

Additionally, when its color fastness to rubbing was measured, the abrasion resistance at level 4 was excellent. Also, industrial cutting and industrial sewing were performed using this dyed cloth and there was no fusion of the cut portions of the cloth at cutting time and there was also very little contamination of the sewing needle, demonstrating outstanding ability to smoothly pass through processing. Furthermore, shirts were made using this material and after they had been worn for one month, a durability test was performed and there was no fluff, whitening or shine, demonstrating outstanding product durability.

[0084]

Embodiment 8

With P5 used in place of P2, melt spinning and drawing were conducted in a manner similar to Embodiment 1 and an 84 dtex, 12 filament drawn yarn was obtained (1 wt% SS). Its spinnability was excellent with only one thread breakage/t and no generation of fluff was observed. However,

although there were almost no problems, compared to Embodiment 1 some fuming was observed directly under the cap. Further, although its drawability was somewhat inferior to that of Embodiment 1, its draw superiority rate was 97% and with the very little amount of fluff adhesion on the guide it was considered to be a sufficient product. The obtained fiber exhibited excellent physical thread properties with a strength of 3.5 cN/dtex, a ductility of 39%, a 7.0% shrinkage in boiling water and a 1.4% U%. Additionally, with a b* value of 1.2, its tone color was excellent with almost no yellow coloration.

[0085]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and there was almost no thread breakage or generation of fluff during the twisting process and the weaving process, demonstrating excellent ability to smoothly pass through processing.

[0086]

Furthermore, this cloth was dyed in a manner similar to Embodiment 1. The obtained fabric exhibited an excellent flexible and soft texture. However, some mechanical creak characteristic of polylactic acid fibers did remain. In addition, its chromogenic properties were excellent but compared to Embodiment 1 some uneven dyeing was observed. This is believed to be because SS is an alkyl substituted fatty acid monoamide and because when compared to the EBA fatty acid bisamide used in Embodiment 1, it reacted easily with the polylactic acid and the effects of the smoothing agent manifested themselves with difficulty and sublimation occurred easily.

[0087]

When its color fastness to abrasion was measured, it was a passing level 3 but compared to Embodiment 1, its abrasion resistance was somewhat

inferior. Additionally, industrial cutting and industrial sewing were conducted using this dyed fabric and compared to Embodiment 1, there was some slight fusion produced in the cut portions of the fabric at cutting time and there was some contamination of the sewing needle but sufficient ability to pass smoothly through processing was sufficiently demonstrated. Furthermore, shirts were made using it and after they had been worn for one month, a durability test was performed and although slightly inferior to Embodiment 1, there was only slight fluff, whitening and shine demonstrating sufficient product durability.

[0088]

Table 1

	Embodiments							
	1	2	3	4	5	6	7	8
Smoothing agent type	EBA	EBA	EBA	EBA	EBA	EBA	KBA	SS
Additive (wt%)	1	4	0.3	1	1	2	1	1
Spinning speed	3000	3000	3000	5000	1500	3000	3000	3000
U%	0.7	1.5	0.7	0.7	1.5	0.9	0.8	1.4
b* value	1.2	3.6	0.8	1.1	1.3	1.2	1.2	1.6
Color fastness to rubbing (level)	4 □	5 ○	3 □	4 □	4 ○	4 □	4 □	3 ○

Uneven dying	0	0	0	0	0	0	0	1
Spinning thread breakage	99	98	99	98	99	98	98	97
(times/t)	2	1	1	2	2	2	2	3
Draw superiority rate (%)								
Loom stoppage								
(times/day·platform)								

EBA: ethylene bisstearic acid amide

KBA: m-xylylene bisstearic acid amide

SS: N-stearyl stearic acid amide

b* value: -1 to 5 is passing

Color fastness to rubbing: 0 and above is passing

Uneven dying: 0 and above is passing

Spinning thread breakage: 4 times/t or less is passing

Draw superiority rate: 90% and above is passing

Loom stoppage: 6 times/day·platform or less is passing

Comparative Example 1

Using only P1 (polylactic acid only) melt spinning and drawing were performed in a manner similar to Embodiment 1 and an 84 cN/dtex, 36 filament drawn yarn was obtained. The obtained fiber had a strength of 3.6 cN/dtex, a ductility of 39%, a 7.5% shrinkage in boiling water and a 0.7% U%. Further, with a b* value of 0.5 the tone color was excellent with almost no yellow coloration.

[0089]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and was dyed. There was mechanical creak characteristic of

polylactic acid fibers in the obtained fabric and it was texturally inferior to Embodiment 1.

[0090]

Additionally, when the color fastness to rubbing was measured, the abrasion resistance had deteriorated to level 1. Further, results from observing the surface of the cloth after the abrasion test with an SEM showed remarkable abrasion of the thread (Figure 2). Also, industrial cutting and industrial sewing were performed using this dyed cloth and at cutting time there was severe fusion of the cut portions of the cloth and acute contamination of the sewing needle showing a very substandard ability to smoothly pass through processing. Furthermore, shirts were made using this material and after they had been worn for one month a durability test was performed and there was pronounced fluff, whitening and shine, demonstrating the inferior durability of the product.

[0091]

Comparative Example 2

With a preparation of PI and P2 made with a weight ratio of 79:1 (0.05 wt% EBA) melt spinning and drawing were performed in a manner similar to Embodiment 1 and an 84 dtex, 36 filament drawn yarn was obtained. The obtained thread had a strength of 3.6 cN/dtex, a ductility of 39%, a 7.5% shrinkage in boiling water and a 0.7% U%. Further, with a b* value of 0.5 the tone color was excellent with almost no yellow coloration.

[0092]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and it was dyed. The obtained cloth was texturally inferior to that of Embodiment 1 exhibiting mechanical creak characteristic of polylactic acid fibers.

[0093]

Furthermore, when the color fastness to rubbing of this material was measured, its abrasion resistance was a substandard level 1. Additionally, industrial cutting and industrial sewing were performed using this dyed material and there was severe fusion of the cut portions of the cloth at cutting time and severe contamination of the sewing needle demonstrating a very inferior ability to smoothly pass through processing. Additionally, shirts were made using this material and after they had been worn for one month a durability test was performed showing remarkable fluff, whitening and shine, demonstrating very inferior product durability.

[0094]

Comparative Example 3

With a preparation made using P3 (7 wt% EBA) in place of P2 melt spinning and drawing were conducted in a manner similar to Embodiment 2 and an 84 dtex, 36 filament drawn yarn was obtained. Because the 7 wt% EBA content amount was excessive, there was remarkable fuming directly under the cap and the work environment had deteriorated. The obtained fiber had a strength of 2.8 cN/dtex, a ductility of 40%, a 5.0% shrinkage in boiling water and a 2.1% U%. Further, with a drawn yarn b* value of 6.1 there was severe coloration showing that if would be difficult to use it for clothing.

[0095]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and it was dyed. The obtained cloth showed conspicuous uneven dyeing and was of inferior quality.

[0096]

Comparative Example 4

Using P6 in place of P2 melt spinning and drawing were performed in a manner similar to Embodiment 1 and an 84 dtex, 36 filament drawn yarn was obtained (1 wt% BA). However, because of thermal resistance and sublimation problems with BA, there was remarkable fuming directly under the cap and the work environment had worsened to an extreme degree. The obtained fiber had a strength of 3.7 cM/dtex, a ductility of 40%, a 7.0% shrinkage in boiling water and a 1.8% U%.

[0097]

A plain weave fabric was made using this thread in a manner similar to Embodiment and was dyed. The obtained cloth exhibited remarkable uneven dyeing and inferior quality.

[0098]

Furthermore, when the color fastness to rubbing of this material was measured, the abrasion resistance at level 1 was inferior. Industrial cutting and industrial sewing were performed using this dyed material and there was severe fusion of the cut portions of the cloth at cutting time, there was also severe contamination of the sewing needle and its ability to smoothly pass through processing was substandard. Additionally, shirts were made using this material and after they were worn for one month, a durability test was performed showing conspicuous fluff, whitening and shine, demonstrating inferior product durability.

[0099]

Comparative Example 5

Using P7 in place of P2 and with a take-up roller circumferential speed of 800 meters per minute and the draw rate magnified four times, melt spinning and drawing were performed in a manner similar to Embodiment 1 and an 84 dtex, 36 filament drawn yarn was obtained (1 wt% SA). However,

because of the thermal resistance and sublimation problems with SA, there was noticeable fuming directly under the cap and the work environment deteriorated to an extreme degree. The obtained fiber had a strength of 3.7 cN/dtex, a ductility of 41%, a 7.0% shrinkage in boiling water and a 2.2% U%.

[0100]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and was dyed. The obtained cloth exhibited remarkable uneven dyeing and inferior quality.

[0101]

Furthermore, when the color fastness to rubbing of this material was measured, the abrasion resistance at level 1 was inferior. Industrial cutting and industrial sewing were conducted using this dyed cloth and there was noticeable fusion with the cut portions of the cloth at cutting time there was conspicuous contamination of the sewing needle demonstrating an inferior ability to smoothly pass through processing. Additionally, shirts were made using this material and after they had been worn for one month, a durability test was performed which showed conspicuous fluff, whitening and shine, demonstrating inferior product durability.

[0102]

Further, from TG (thermogravimetry), when determining the depreciation rate from heating of the SA, a 4.1% decrease in weight was found at 250ºC. In contrast, for the case of the fatty acid bisamide EBA, at 250ºC the weight reduction was only 0.5% showing that the fatty acid bisamide when compared to the fatty acid monoamide had excellent thermal resistance and was difficult to sublime.

[0103]

[Table 2]

	Comparative examples				
	1	2	3	4	5
Smoothing agent type		EBA	EBA	BA	SA
Additive (wt%)	0	0.05	7	1	1
Spinning speed (meters per minute)	3000	3000	3000	3000	800
U%	0.7	0.7	2.1	1.8	2.2
b* value	0.5	0.5	6.1	3.8	4.2
Color fastness to rubbing	1	1	5	1	1
(level)	□	□	×	△	×
Uneven dyeing					

EBA: ethylene bisstearic acid amide

BA: behenic acid amide

SA: Stearic acid amide

b* value: -1to 5 is passing

Color fastness to rubbing: level 3 and above is passing

Uneven dyeing: ○ and above is passing

Embodiment 9

A spinning oil agent (15% concentration) containing a fatty acid ester based 65 wt% smoothing agent (isotridecyl stearate 35wt% + octylpalmitate 30wt%) was used as the spinning oil agent, melt spinning and drawing were performed in a manner similar to Embodiment 1 and an 84 dtex, 24 filament drawn yarn was obtained. Its spinnability was excellent and no thread breakage or generation of fluff was observed. Furthermore, its drawability was also excellent with a draw superiority rate of over 98% and no adhesion of fluff to

the guide was observed. The obtained fiber exhibited excellent physical thread properties with a strength of 3.5 cN/dtex, a ductility of 40%, a 7.0% shrinkage in boiling water and a 0.7% U%. Additionally, with a 1.2 b* value the tone color was excellent with almost no yellow coloration.

[0104]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and there was no thread breakage or generation of fluff during the twisting process and weaving process, demonstrating an outstanding ability to smoothly pass through processing. Furthermore, at this time its weaving performance was excellent even compared to Embodiment 1 and it was possible to raise the weaving speed and to increase productivity.

[0105]

Furthermore, this fabric was dyed in a manner similar to Embodiment 1 and the obtained cloth was flexible and soft and its texture was excellent with very little mechanical creak characteristic of polylactic acid fibers. In addition, along with its excellent chromogenic properties there was no uneven dyeing and its quality was outstanding.

[0106]

Further, when its color fastness to rubbing was measured, its abrasion resistance at level 4 was excellent. Additionally, industrial cutting and industrial sewing were performed using this dyed cloth and there was no fusion of the cut portions of the cloth at cutting time and only very slight needle contamination, demonstrating an outstanding ability to pass through processing. Also, shirts were made using this material and after they had been worn for one month, a durability test was performed and there was no fluff, whitening or shine, demonstrating outstanding product durability.

[0107]

Embodiment 10

A spinning oil agent containing a fatty acid ester based 50 wt% smoothing agent (isotridecyl stearate 25 wt% + octyl palmitate 25 wt%) and 20 wt% mineral oil was used, melt spinning and drawing were performed in a manner similar to Embodiment 1 and an 84 dtex, 24 filament drawn yarn was obtained. Its spinnability was excellent and no thread breakage or fluff generation was observed. Further, its drawability was also excellent with a draw superiority rate of over 98% and no adhesion of fluff to the guide was observed. The obtained fiber exhibited excellent physical fiber properties with a strength of 3.5 cN/dtex, a ductility of 40%, a 7.0% shrinkage in boiling water and a 0.7% U%. Also, with a b* value of 1.2 the tone color was excellent with almost no yellow coloration.

[0108]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and there was no thread breakage or generation of fluff in the twisting process and weaving process, demonstrating an excellent ability to smoothly pass through the weaving process. Additionally, at this time its weaving performance was excellent compared to Embodiment 1 and it was possible to raise the weaving speed and increase productivity.

[0109]

Further, this cloth was dyed in a manner similar to Embodiment 1. The obtained cloth was flexible and soft and exhibited an outstanding texture with very little mechanical creak chararacteristic of polylactic acid fibers. Also, in addition to have outstanding chromogenic properties, there was also no uneven dyeing and the quality was excellent.

[0110]

Furthermore, when the color fastness to rubbing of this material was measured, its abrasion resistance at level 4 was excellent. Additionally, industrial cutting and industrial sewing were performed using this dyed cloth and there was no fusion of the cut portions of the cloth at cutting time and only slight sewing needle contamination, demonstrating an excellent ability to smoothly pass through processing. Also, shirts were made using this material and after they had been worn for one month, a durability test was performed and there was no fluff, whitening or shine demonstrating outstanding product durability.

[0111]

Embodiment 11

A spinning oil agent (15% concentration) containing a 15 wt% smoothing agent (isotridecyl stereate 15 wt%) for the fatty acid ester thread and 75 wt% polyether was used as the spinning oil agent and in a manner similar to Embodiment 1 melt spinning and drawing were performed and an 84 dtex, 24 filament drawn fiber was obtained. Compared to Embodiments 1 to 10, although thread breakage during spinning and drawing had increased and there was an increase in adhesion of the fluff on the guide, it exhibited sufficient spinnability and drawability. The obtained fiber demonstrated excellent physical fiber properties with a strength of 3.3 cN/dtex, a ductility of 32%, a 7.0% shrinkage in boiling water and a 1.2% U%. Further, with a 1.2 b* value the color tone was excellent with almost no yellow coloration.

[0112]

A plain weave fabric was made using this thread in a manner similar to Embodiment and although, compared to Embodiments 1 to 10, there was an increase in thread breakage and generation of fluff at the time of the twisting

process and weaving process, sufficient ability to pass smoothly through processing was demonstrated.

[0113]

Furthermore, this fabric was dyed in a manner similar to Embodiment 1. The obtained cloth was flexible and soft and exhibited an outstanding texture with very little mechanical creak characteristic of polylactic acid fibers. Also, in addition to its excellent chromogenic properties, there was very little uneven dyeing and the quality was excellent.

[0114]

Additionally, when the color fastness to rubbing of this material was measured, its abrasion resistance at level 4 was excellent. Also, industrial cutting and industrial sewing were performed using this dyed cloth and there was no fusion of the cut portions of the cloth at cutting time and only very slight sewing needle contamination demonstrating an excellent ability to smoothly pass through processing. Also, shirts were made using this material and after they had been worn for one month, a durability test was performed and there was no fluff, whitening or shine, demonstrating outstanding product durability.

[0115]

Embodiment 12

A spinning oil agent (15% concentration) containing a fatty acid ester based 15 wt% smoothing oil agent (isotridecyl stearate 15 wt%) and 75 wt% polyether was used , melt spinning and drawing were performed in a manner similar to Embodiment 4 and an 84 dtex, 24 filament drawn yarn was obtained. Compared to Embodiment 4, there was an increase in thread breakage in the spinning and drawing and also an increase in adhesion of fluff on the guide but spinnability and drawability were sufficient. The obtained fiber had a strength of

3.0 cN/dtex, a ductility of 15%, 8.0% shrinkage in boiling water and a 1.2% U%. Additionally, with a 1.2 b* value, the tone color was excellent with almost no yellow coloration.

[0116]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and compared to Embodiment 4 there was quite an increase in thread breakage and fluff generation during the twisting process and weaving process demonstrating insufficient ability to smoothly pass through processing.

[0117]

Additionally, this cloth was dyed in a manner similar to Embodiment 1. The obtained cloth was flexible and soft and exhibited an outstanding texture with little mechanical creak characteristic of polylactic acid fibers. Also, in addition to having excellent chromogenic properties, there was only slight uneven dying and the quality was excellent.

[0118]

Furthermore, when the color fastness to rubbing of this material was measured, its abrasion resistance at level 4 was excellent. Additionally, industrial cutting and industrial sewing were performed using this dyed cloth and there was no fusion of the cut portions of the cloth at cutting time and only very slight sewing needle contamination demonstrating an excellent ability to smoothly pass through processing. Also, shirts were made using this material and after they had been worn for one month, a durability test was performed and there was no fluff, whitening or shine, demonstrating outstanding product durability.

[0119]

Table 3

		Embodiment			
		9	10	11	12
Smoothing oil agent content amount (wt%) in oil agent	Fatty acid ester	65	50	15	15
	Mineral oil	0	20	0	0
	Polyether	0	0	75	75
Spinning speed (meters per minute)		3000	3000	3000	3000
U%		0.7	0.7	1.2	1.2
b* value		1.2	1.2	1.2	1.2
Color fastness to rubbing (level)		4	4	4	4
Uneven dyeing		◎	◎	○	○
Spinning thread breakage (times/t)		0	0	4	7
Draw superiority rate (%)		99	99	91	85
Loom stoppage (times/day·platform)		0	0	6	10

b* value: -1 to 5 is passing

Color fastness to rubbing (level): 3 and above is passing

Uneven dyeing: O and above is passing

Spinning thread breakage: 4 times/t or less is passing

Draw superiority rate: 90% and above is passing

Loom stoppage: 6 times/day·platform and below is passing

Embodiment 13

A static kneader (Toray Engineering Co., Ltd. made [High Mixer] 10 stage) was inserted onto the spinning pack 4 and in a manner similar to Embodiment 2 melt spinning and drawing were performed and an 84 dtex, 36 filament drawn yarn obtained. Its spinnability was excellent and no thread breakage or generation of fluff was observed. Further, its drawability was also excellent with a draw superiority rage of 99% and no adhesion of fluff on the guide was observed. The obtained fiber exhibited excellent physical fiber properties with a strength of 3.5 cN/dtex, a ductility of 40%, a 7.0% shrinkage in boiling water and a 0.8% U%. In addition, with a b* value of 3.0 the color tone was excellent with almost no yellow coloration.

[0120]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and at the time of the twisting process and the weaving process there has almost no thread breakage or generation of fluff, demonstrating an outstanding ability to pass smoothly through processing.

[0121]

Furthermore, this fabric was dyed in a manner similar to Embodiment 1. The obtained cloth was flexible and soft and exhibited an outstanding texture with little mechanical creak characteristic of polylactic acid fibers. Also,

in addition to its excellent chromogenic properties there was no uneven dyeing and the quality was superior.

[0122]

Additionally, when its color fastness to rubbing was measured, its abrasion resistance at level 4 was excellent. Further, industrial cutting and industrial sewing were performed using this dyed fabric and there was no fusion on the cut portions of the cloth at cutting time and also very little sewing needle contamination demonstration an outstanding ability to smoothly pass through processing. Also, shirts were made using this material and after they had been worn for one month, a durability test was performed and no fluff, whitening or shine was found, demonstrating excellent product durability.

[0123]

Embodiment 14

A chip blend of P1 and P2 with a weight ration of 3:1 was made, placed in hopper 1 and after this chip was melted at 220ºC in extruder 2, the melted polymer was introduced into the spinning pack 4 positioned in spin block 3 which was heated to 220ºC and extruded from the cap 5 (Figure 5). After the spun twisted thread line 7 was air cooled and solidified at 25ºC by the chimney 6, the spinning oil agent (15% concentration) containing a 40wt% fatty acid ester (isotridecyl stearate 20 wt% + octylpalmitate 20 Wt%) was 1 wt% applied with respect to the thread by the focused lubrication guide 8 and a twist was given to the thread by the twist guide 9. Then, after it was drawn and heat processed between the first hot roller 19 at a circumferential speed of 3000 meters per minute and at 95ºC and the second hot roller 20 with a circumferential speed of 4500 meters per minute and at 135ºC, the 84 dtex, 36 filament round cross sectional wound up thread 21 was obtained. Its spinnability was excellent and

no thread breakage or generation of fluff was observed. Also, there were almost no fumes directly under the cap.

[0124]

The obtained fiber exhibited excellent physical thread properties with a strength of 3.5 cN/dtex, a ductility of 40%, a 7.0% shrinkage in boiling in water and a 0.7% U%. Additionally, with a b* value of 1.2 the tone color was excellent with almost no yellow coloration.

[0125]

A plain weave fabric was made using this thread in a manner similar to Embodiment 1 and there was almost no thread breakage or generation of fluff during the twisting process and weaving process, demonstrating an outstanding ability to smoothly pass through processing.

[0126]

Additionally, this fabric was dyed in a manner similar to Embodiment 1. The obtained cloth was flexible and soft and exhibited an outstanding texture with little mechanical creak characteristic of polylactic acid fibers. Further, in addition to its excellent chromogenic properties, there was no uneven dyeing and the quality was exceptional.

[0127]

Furthermore, when the color fastness to rubbing of this material was measured, its abrasion resistance at level 4 was outstanding. Also, industrial cutting and industrial sewing were performed using this dyed cloth and at cutting time there was no fusion of the cut portions of the cloth and very little sewing needle contamination, demonstrating an outstanding ability to smoothly pass through processing. Additionally, shirts were made using this fabric and after

they had been worn for one month, a durability test was performed and there was no fluff, whitening or shine, demonstrating excellent product durability.

[0128]

Embodiment 15

Drawing and false twisting by the device shown in Figure 6 was performed on the undrawn yarn obtained in Embodiment 4. At this time the temperature of the heater 23 was 130ºC, the draw magnification between the feed roller 22 and the draw roller 26 was 1.35, the speed of the draw roller 26 was 400 meters per minute, the temperature of the second heater 27 was 150ºC and the relax rate between the draw roller 26 and the delivery roller 28 was 6% and a triaxial twister was used as the false twisting rotator 25. Furthermore, the cooling plate 24 was placed between the heater 23 and the false twistingrotator 25. In this manner, the 109 dtex, 36 filament twisted thread 29 was obtained. The CR value of this twisted thread was 20% exhibiting sufficient twisting properties. Also, its strength was 2.5 cN/dtex, its ductility was 25% and its shrinkage in boiling water was 6.2%. Additionally, with a b* value of 1.3 its tone color was excellent with almost no yellow coloration.

[0129]

A twill fabric (fabric density: warp 95 stiches/inch, woof 80 stiches/inch) was made using this thread in the warp and woof. Further, both the warp and woof had an S twist of 300 turns per meter. There was almost no thread breakage or generation of fluff in the twisting process and weaving process, demonstrating an excellent ability to smoothly pass through processing. Additionally, this fabric was dyed in a manner similar to Embodiment 1. The obtained cloth was flexible and soft and exhibited a superior texture with very little mechanical creak characteristic of polylactic acid fibers. Also, in addition

to its excellent chromogenic properties, there was no uneven dyeing and its quality was outstanding.

[0130]

Furthermore, when its color fastness to rubbing was measured, its abrasion resistance at level 4 was excellent. Also, industrial cutting and industrial sewing were performed using this fabric and at cutting time there was no fusion of the cut portions of the fabric and very little contamination of the sewing needle, demonstrating an excellent ability to smoothly pass through processing. Additionally, shirts were made using this fabric and after they had been worn for one month, a durability test was performed in which there was no fluff, whitening or shine, demonstrating outstanding product durability.

[0131]

[Effect of the invention]

With the outstanding abrasion resistance and excellent ability to smoothly pass through processing of the polylactic acid fiber of this invention, it is possible to significantly expand the applicable developmental range of polylactic acid fibers.

[Brief description of the diagrams]

[Fig. 1] A diagram showing the abrasion state of the polylactic acid fiber of this invention

[Fig. 2] A diagram showing the abrasion state of a conventional polylactic acid fiber

[Fig. 3] A diagram showing the spinning equipment

[Fig. 4] A diagram showing the drawing equipment

[Fig. 5] A diagram showing the spin direct drawing equipment

[Fig. 6] A diagram showing the drawing and false twisting equipment

[Explanation of the coding]

1: Hopper

2: Extruder kneader (extruder)

3: Spin block

4: Spinning pack

5: Cap

6: Chimney

7: Thread line

8: Focused lubrication guide

9: Twist guide

10: No. 1 take-up roller

11: No. 2 take-up roller

12: Wound yarn

13: Undrawn yarn

14: Feed roller

15: No. 1 hot roller

16: No.2 hot roller

17: Cold roller

18: Drawn yarn

19: No. 1 hot roller

20: No. 2 hot roller

21: Wound yarn

22: Feed roller

23: Heater

24: Cooling plate

25: Rotator

26: Draw roller

27: Second heater

28: Delivery roller

29: Crimped yarn

Fig. 1

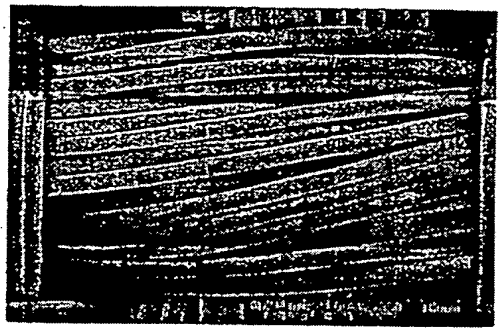

Fig. 2

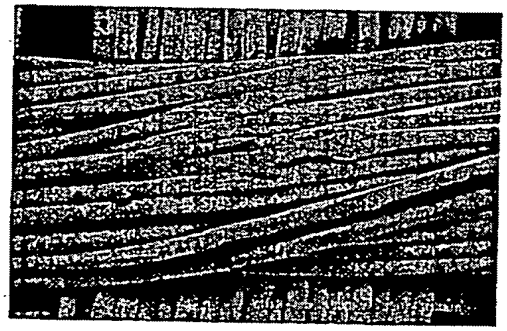

Fig. 3

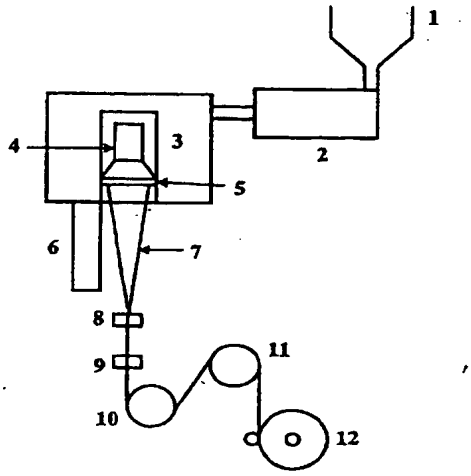

Fig. 4

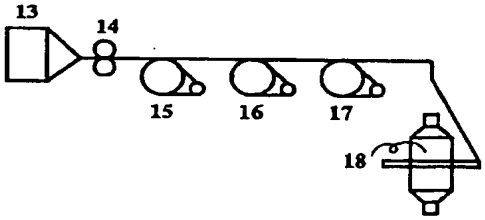

Fig. 5

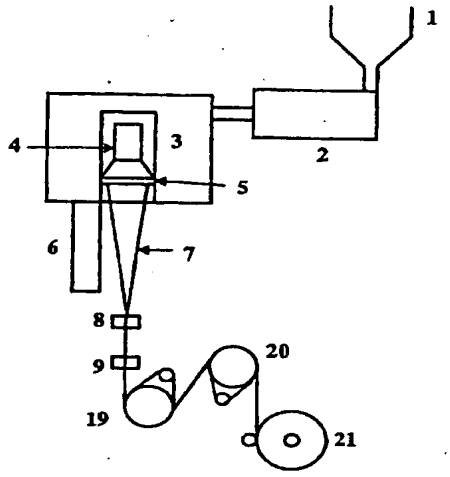

Fig. 6